Space Weather Technical Forecast

Issued on Sunday, 07 January 2024 at 00:40 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Ongoing Chance of R1. Slight Chance of G1 throughout, with full CME analyses pending. Waning Chance of S1.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity, as measured by GOES16 was Low, with frequent low to mid-ranking C-class flares and with a peak of C7.1 seen at 06/1535UTC from sunspot region AR3538 in the northwest quadrant. This group finished the 24 hours as a Cai/Beta-Gamma-Delta.

There were around ten sunspot regions on the disc, with eight of these numbered, although the partitioning of groups is complex given their proximity to each other. Also complicating analyses was the fact that the majority of these sunspot regions comprised numerous small and mobile umbrae. The main observed trends in the 24 hours were proliferation and spreading of minor spots in AR3539, AR3538 and a new region near south centre-disc. AR3536 saw minor fading of some of its southern spots, while AR3540 saw some minor spot growth. Tenuous delta spots were possibly present in AR3538 and AR3540.

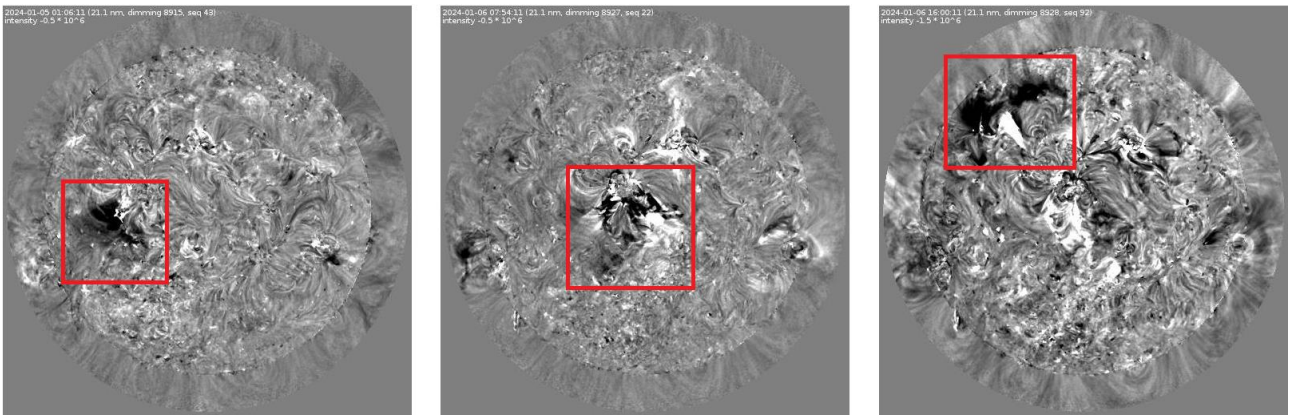

Figure 0: SIDC ROB time-integrated AIA 211 coronal dimmings of two possible Earth-bound CMEs and a third of interest, respectively from the southeast quadrant on 04 January; east-centre disc on 06 January and the northeast quadrant, also on 06 January. The first two events feature in the geomagnetic forecast, with the third awaiting imagery for analysis.

There were two main CME-generating events observed in the 24 hours: firstly one associated with a filament eruption just east of centre-disc around 06/0620UTC, with ejecta visibly leaving the disc south and east of the Sun-Earth line on subsequent AIA304 imagery. Secondly, a filament eruption was seen to emerge from the northeastern quadrant around N30E030 at 06/1330UTC, leaving a filament channel and faint ribbon flares in its wake on AIA304. This event is now becoming visible in coronagraphs, but is polluted by a concurrent far-side event at similar solar latitude. At the time of writing, only the former front-sided CME has been tentatively analysed, with Lasco C2 and a single frame of STEREO A COR2. Provisionally, this CME passes 1AU around the turn of the UTC day 09 into 10 January as a very slight glance, however further analyses will be sought to confirm

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this. Further imagery is awaited for the later CME.

A final CME seen on evening Lasco C2 imagery heading south was of uncertain source but could not be reconciled with any activity on the front side. Further imagery is required to confirm this.

Solar Wind / Geomagnetic Activity: Solar winds, as measured at L1 by ACE and DSCOVR showed level but differing values near background levels in an apparent slow regime. The solar wind speed was variously described as in the low 300s or else high 400s by each satellite, with the former perhaps preferred (ACE) given the expected slow regime, and the fact that the solar wind density and IMF were otherwise small-scale and unremarkable (within single figures ppcc and below 3nT respectively, with a north-south component of +2/-3nT). The phi angle was mostly negative (towards the Sun).

The net result of the above solar wind measures was for provisionally Quiet geomagnetic activity throughout.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux continued its inexorable decline of recent days towards resting background levels in falling from near 6 to near 2pfu (i.e. below S1).

GOES16 high energy (greater than 2MeV) electron flux was at Normal Background levels. The 24-hour fluence was below Active throughout, with a flat trend. The 07/0001UTC observation was 2.26e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: There is a level daily Chance of M-class flares throughout, and a Slight Chance of X-class.

Solar Wind / Geomagnetic Activity: Up to two CMEs feature at present and one fast wind regime. The most likely course of events is for the fast wind to arrive within the first 24 hours, with the northeast quadrant CME from 04 January then due in the following 24 and the second east-central CME from 06 January perhaps following after yet another 24 hours - each with decreasing confidence.

The net result is a falling Slight Chance of G1 through the four days, perhaps most reliably Quiet at the very start and end of the period.

Energetic Particles / Solar Radiation: In the absence of further proton-rich flares in prone locations, levels may be allowed to relax back to resting background before the middle of the coming UTC working week, with a Chance of S1 falling to a Slight Chance with time.

High-energy electrons at GEO are expected to remain at Normal Background levels in the near-term, with a rising Slight Chance of Active 24-hour integrated fluence before midweek UTC in the wake of CH89's fast wind and in the possible absence of significant CME effects.

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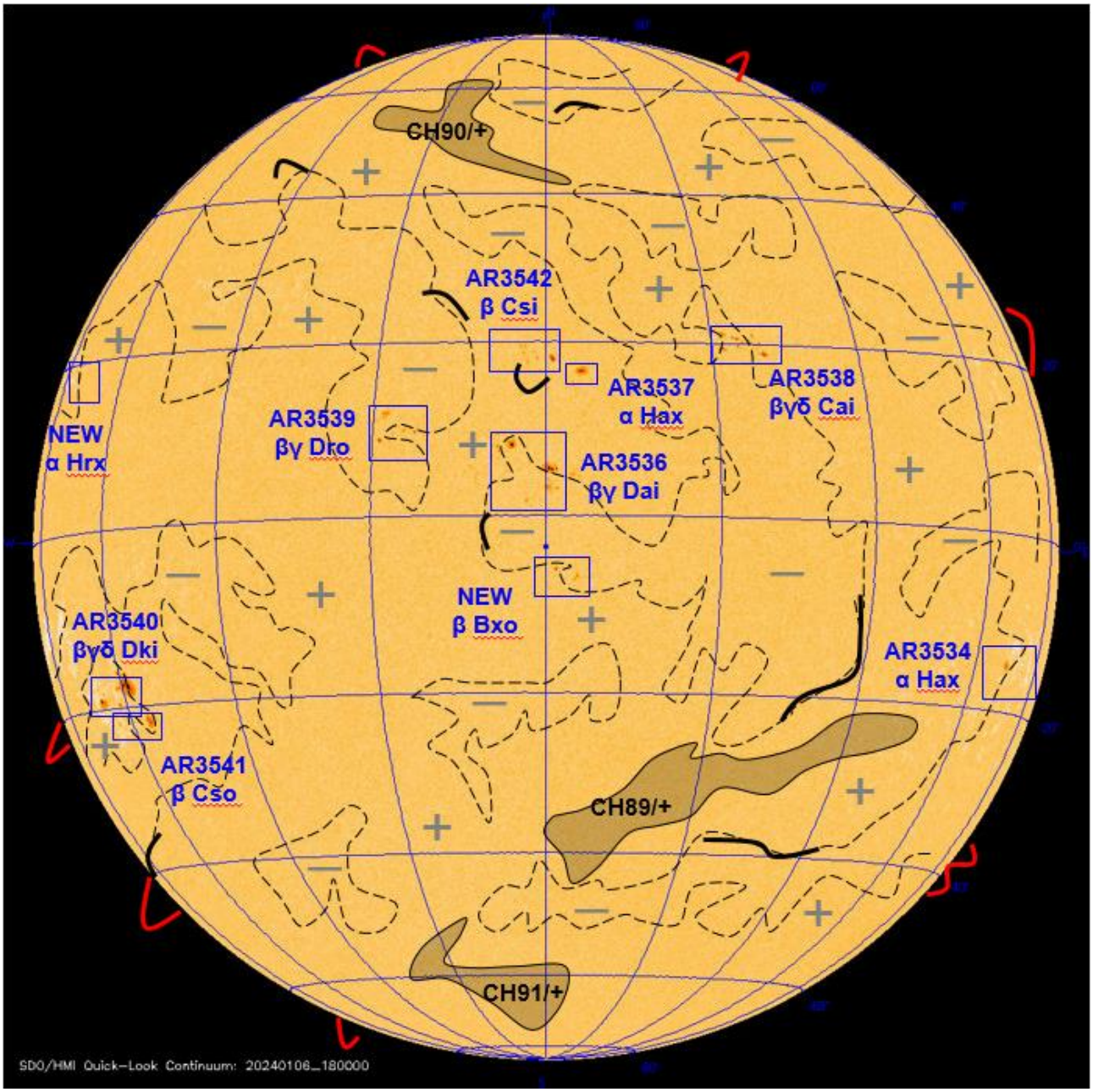
Figure 1. Solar Analysis Valid 06/1800UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

Two CMEs feature in the current forecast, although the second is from a very rudimentary analysis. The first originated from the northeastern quadrant on 04 January (but directed southeastward) and is forecast to perhaps glance the Earth either late on Day 2 (Monday 08 January) or else during Day 3 (Tuesday 09 January). Secondly, the filament eruption observed at 06/0620UTC has been provisionally determined to pass 1AU around the turn of the UTC day Tuesday 09 into Wednesday 10 January as a very slight glancing blow. Confidence in this second CME is especially low given that the analysed CME appeared to be better described by a more eastward-directed CME than its departure point on the disc might suggest (i.e. it apparently did not leave purely radially outward).

Earth is currently thought to be transiting a sector of space dominated by a slow solar wind regime. A fast wind from coronal hole 89 may interrupt this later in the current UTC day of 07 January, with speeds in the region of 450-500km/s possible. These speeds should then continue until slowly waning through Tuesday 09 January. This coronal hole is a recurrent feature which produced limited effects on the previous rotation, but which appears to be visually stronger on this rotation. Possibly mitigating against any significant effects are its relative location well south of the solar equatorial plane. As the coronal hole high speed stream and first CME are forecast to affect the Earth around the same time, there is uncertainty about potential speeds, with the speed of the CME also forecast at around 400-450km/s.

The result of the above factors is a relatively glib residual Slight Chance of G1 throughout the four-day period, probably greastest in the first half under the possible combined influence of the fast wind (or its CIR) and the CME, with the second half of very low confidence and perhaps lapsing to Quiet conditions instead. The second CME will be further analysed as imagery allows.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	20	20	10	10
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

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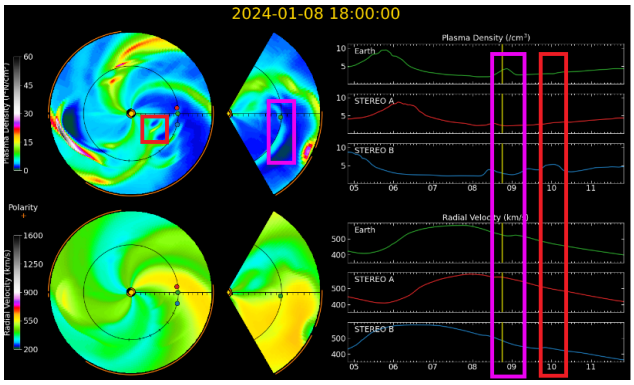
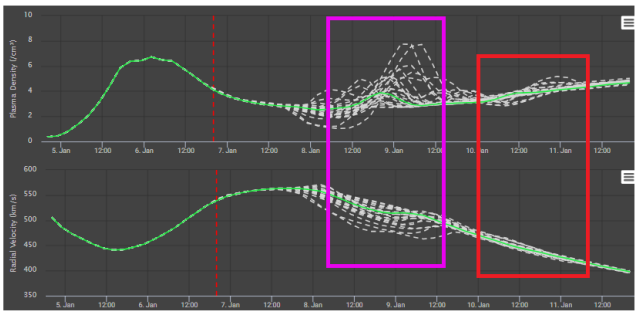
Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
05/1746	Partial?	Filament	NE	393	At or after 08/1800UTC	Low confidence
06/2014	Partial?	Filament	E central	480	At or after 10/0001UTC	Tentiave analysis, mainly S and E of Sun-Earth line.

Figure 2: Latest MOSWOC Enlil model and ensemble (badge time 06/2000UTC), showing up to two provisionally inbound CMEs: firstly the 04 January NE quadrant CME in magenta, and secondly the E-central 06 January CME passing 1AU around the turn of the UTC day 09 into 10 January. Both a relatively low confidence glancing blows, the latter especially.





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Radio Blackouts - X-Ray Flares:

The current Earth-facing disc is dominated by diffuse and closely-spaced plage regions harbouring sunspot regions of many small pores and umbrae. A lot of these are magnetically bipolar and display gamma Mt Wilson complexity, despite overall simpler Zurich classifications. Tenuous delta spots are also possible in AR3540 in the southeast, which is nominally the most complex region at a Dki/Beta-Gamma-Delta, as well as the largest areally, although recent activity has instead been dominated by AR3538 in the northwest, the latter a Cai/Beta-Gamma-Delta.

No notable regions from this congested front-side leave the disc in the four-day period. In terms of potential arrivals, there is a tentatively busier outlook possible, with some bright EUV flux looping on the eastern limb in AIA171 and with the returning Carrington locations for many regions due over the eastern limb into the new UTC week.

For now, the daily Chance of M-class flares and Slight Chance of X-class is maintained as per raw values for the Zurich classes of the disc.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	No	50	50	50	50
Very Active	R3 to R5 X Class	No	10	10	10	10

Figure 3: SIDC ROB-processed PROBA2 X-ray flares of C-class and above over the 24 hours to 07/0020UTC, with sources fairly well-distributed, but with the possible Mt Wilson delta-containing regions of AR3538 (in the northwest) and AR3540 (in the southeast) dominant.

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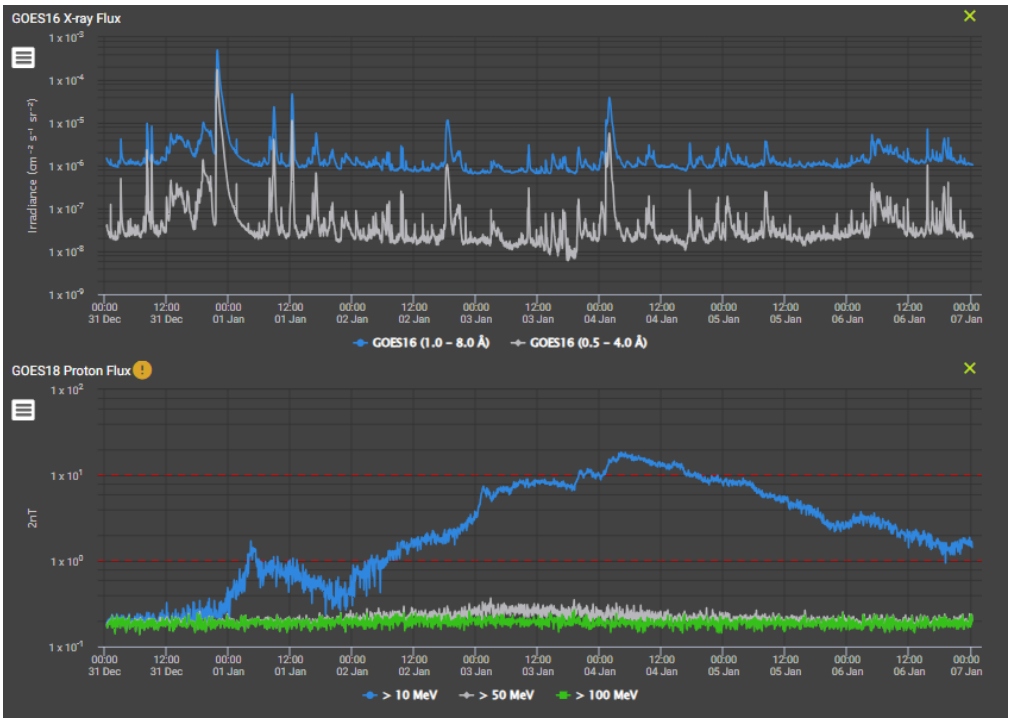
Solar Radiation Storms - (High Energy Protons):

GOES16 high energy (greater than 10MeV) proton flux remains above resting background levels in the wake of the possible generating X-class flare that greeted the new year. The soft spectrum and very gradual rise and fall certainly suggest a far-side or east limb source. Flux levels will most likely continue their very gradual relaxing trend in the coming days, however inbound CMEs may compress some of the inbound trickle of protons into a larger pulse, which overall leads to an initial Chance of S1 - i.e a little above that suggested by the raw disc probabilities (nearer 10% daily risk).

In the absence of further proton-rich flares in prone locations, levels may be allowed to relax back to resting background before the middle of the coming UTC working week, with a Chance of S1 falling to a Slight Chance with time.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	25	20	20	10
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: Past week in GOES16 X-ray flux and GOES18 proton flux (GOES16 has a diurnal artefact around local midnight). Note the damped response to the probable X-class source, with the downward trend most likely to continue, but with a slightly higher risk of further enhancements to S1 in the interim, given appropriate flares.



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High Energy Electrons Event (≥ 2MeV):

The current languid behaviour of high energy electron flux (greater than 2MeV) at GEO is expected to continue in the near-term in the absence of any fast wind enhancement and with the uncertainty tied to inbound CMEs. Should CH89/+ materialise into the new UTC working week, there may be an eventual slight increase observed, although both persistence and the expected strength of any fast wind suggest that this is perhaps only an eventual Slight Chance. This may be further dented by any second inbound CME, and the presence of this and the earlier transient are likely to render confidence in MOSWOC REFM relatively low throughout, even if its suggested trend happens to be the favoured scenario - as now.

GEO Electron Environment	**Level (cm^{-2} sr^{-1} day^{-1})**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability (Exceedance)			**(%)**	**(%)**	**(%)**	**(%)**
Active	**≥ 2 MeV ≥ $1x10^{8}$**	No	1	1	10	20
Very Active	**≥ 2 MeV ≥ $1x10^{9}$**	No	1	1	1	1

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